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COMMODITY MARKET HETEROGENEITY AND CROSS-MARKET INTEGRATION

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Abstract: We evaluate the recent levels of heterogeneity and cross-market integration for fluctuations in commodity futures returns for a post-financial-crisis data sample. We find that a single commodity-market risk factor explains 30.6% of the total variation in commodity futures returns. The commodity-market risk factor is significantly correlated with the dominant market-wide risk factors from other asset classes: +66.7% with a market risk factor for the US equity market; -74.2% with a US dollar risk factor for the FX market; and -27.8% with an interest-rate level risk factor for the US interest rate market. Thus, a part of the systematic variation in the commodity market is integrated with other asset classes.

Keywords: Commodity Market; Cross-Market Integration

1. Introduction

The commodity market offers diversification benefits from traditional asset classes such as stocks and bonds (for a review, see Skiadopoulos, 2013). However, to make informed decisions, investors need to measure the level of heterogeneity within the commodity market and the level of integration between the commodity market and other asset classes. The purpose of this paper is to measure both the level of heterogeneity and the level of cross-market integration of the commodity market for a post-financial-crisis data sample.

A strand of research has found that the commodity market is heterogeneous (Erb and Harvey, 2006; Kat and Oomen, 2007; Daskalaki et al., 2014). Historically, commodity futures returns have been shown to be largely uncorrelated with one another (Erb and Harvey, 2006). The heterogeneous structure of the commodity market makes it more difficult to identify systematic risk factors that may price common variation of commodity futures returns (Daskalaki et al., 2014). Furthermore, Skiadopoulos (2013) concludes that there are no common, or systematic, risk factors in commodity futures returns because, as an asset class, it is internally segmented. However, it has been suggested that recent increases in commodity return correlations are caused by investment in commodity indices (Tang and Xiong, 2012).

In contrast, another strand of research has proposed a number of common risk factors to explain fluctuations in commodity futures returns. Empirically, it has been reported that the average of the annualized individual commodity futures excess returns is approximately zero (Erb and Harvey, 2006). However, there is an observed equity-like average return of rebalanced equally weighted portfolios of commodity futures (Bodie and Rosansky, 1980; Erb and Harvey, 2006; and Gorton and Rouwenhorst, 2006). The rebalancing effect has directed research into long-short strategies in the commodity market.

Miffre (2016) provides an extensive review of long-short strategies in the commodity market, such as roll-yields, inventory levels, hedging pressure and past performance. Szymanowska et al. (2014) found three risk factors: one factor for spot premia, and two factors for term premia. Miffre and Fernandez-Perez (2015) find that commodity portfolios based on momentum, term structure or hedging pressure can achieve a lower correlation with the S&P 500 when compared to long-only commodity portfolios. More specifically, Basu and Miffre (2013) found a single risk factor based on hedging pressure. Additionally, Gorton et al. (2013) argue that fluctuations in commodity futures risk premiums depend on the level of physical inventories. Finally, Hong and Yogo (2012) use the growth rate in open interest as a predictor of commodity futures returns.

More generally, the commodity market appears to be segmented, rather than integrated, from other asset classes (Buyuksahin et al., 2010; Chong and Miffre, 2006; and Daskalaki et al., 2014). There is a reported small negative correlation between commodity returns against both equity and bond returns (Buyuksahin et al., 2010; Gorton and Rouwenhorst, 2006; and Greer, 2000). Skiadopoulos (2013) argues that the commodity market is segmented from both equity and bond markets. Similarly, Daskalaki, et al., (2014) argue that the commodity market is segmented from the equity market. In addition, Chong and Miffre (2006) provide historical evidence that commodity and equity markets have become more segmented.

In contrast, evidence for integration between the commodity market and other asset classes is less prevalent (Silvennoinen and Thorp, 2010; and Tang and Xiong, 2010). Silvennoinen and Thorp (2013) provide evidence of closer integration between commodity and financial markets based on increases in financial traders' open interest. The increase in open interest leads into the wider literature on the financialization of the commodity market (for a review, see Haase et al., 2016). The financialization of the commodity market results in commodity futures prices being determined by the aggregate risk appetite for financial assets (Tang and Xiong, 2012). Daskalaki and Skiadopoulos (2011) provide evidence that the financialization of commodity markets may reduce its diversification benefits from traditional asset classes.

Standard multifactor models are traditionally used to measure both the level of heterogeneity and the level of cross-market integration. Examples of different types of standard multifactor models applied to the commodity market can be found in Daskalaki et al. (2014).

Integrated multifactor models have been proposed to aggregate local multifactor models (Stefek, 2002; Anderson et al., 2005; Shepard, 2007). The central idea is to further decompose local systematic risk factors into global systematic and purely local contributions (Shepard, 2011). Not only does the integrated multifactor model allow for the inclusion of more risk factors, it also allows for the inclusion of specific cross-market correlations among individual local risk factors (Shepard, 2007). An integrated multifactor model may also be nested to add multiple levels of increasing resolution (Shepard, 2007).

We contribute to the literature by using a multilevel (or nested) integrated multifactor model, rather than the standard multifactor models, to measure both the level of heterogeneity within the commodity market and the level of cross-market integration between the commodity market and other asset classes. Furthermore, the multilevel integrated multifactor model allows for the inclusion of multiple futures for each commodity, interest rate, equity index and exchange rate.

At the commodity-market level, we find that a single commodity-market risk factor explains 30.6% of the total variation in commodity futures returns. At the less granular sector level, we find that six sector-level risk factors explain 60.7% of the total variation in commodity futures returns. Thus the commodity market has different levels of heterogeneity.

We also find that approximately 25% of the commodity market is integrated with, rather than segmented from, other asset classes. An implication of this finding is that the commodity market may not offer the level of diversification that is currently expected by investors.

2. Material and methods

2. 1. Multifactor models in each level

A multilevel integrated multifactor model is nested across many levels. At level *n* we define the *i*th linear multifactor model, in matrix notation, as:

$$\mathbf{r}_i^n = \mathbf{X}_i^n \mathbf{f}_i^n + \mathbf{u}_i^n \qquad i = 1, \ldots, M^n \qquad (1)$$

where $\mathbf{r}_i^n$ is a N_i^n vector of security returns; $\mathbf{X}_i^n$ is a $N_i^n \times K_i^n$ matrix of risk factor sensitivities; $\mathbf{f}_i^n$ is a K_i^n vector of risk factors; and $\mathbf{u}_i^n$ is a N_i^n vector of security specific (idiosyncratic) returns. For levels beyond one (n>1), the *i*th vector of security returns consists of a selection of the risk factors from the previous level (n-1).

The total covariance matrix of the security returns for the *i*th linear multifactor model in level *n* can be decomposed in terms of the systematic risk factors by:

$$\mathbf{V}_i^n = \mathbf{X}_i^n \mathbf{F}_i^n \mathbf{X}_i'^n + \mathbf{\Delta}_i^n = \mathbf{\Sigma}_i^n + \mathbf{\Delta}_i^n \qquad i = 1, \ldots, M^n \qquad (2)$$

where $\mathbf{V}_i^n$ is an $N_i^n \times N_i^n$ total covariance matrix of the security returns, $\mathbf{\Sigma}_i^n = \mathbf{X}_i^n \mathbf{F}_i^n \mathbf{X}_i'^n$ an $N_i^n \times N_i^n$ systematic covariance matrix of the security returns, $\mathbf{F}_i^n$ is a $K_i^n \times K_i^n$ covariance matrix of the systematic risk factors and $\mathbf{\Delta}_i^n$ is a positive definite $N_i^n \times N_i^n$ security specific covariance matrix of the security returns.

2. 2. Data

We use a post-financial-crisis data sample, where for all securities we use six years of monthly data from Bloomberg from 31st December 2009 to 31st December 2015. Our data sample is time independent from previous studies, with the exception of one year in common (2010) with Daskalaki, et al. (2014). We also use a larger sample of commodity futures than previous studies.

The commodity-market data sample consists of the three future contracts that are closest to maturity for 34 commodities: a total of 34 x 3 = 102 futures. Each commodity is grouped into one of five commodity sectors: energy, grains, livestock, metals and softs. These include six energy (kerosene, heating oil, crude oil, gas oil, gasoline, natural gas), ten grains (wheat, corn, crude palm oil, soybean oil, soybean, soybean meal, canola, oats, rough rice, red beans), three livestock (feeder cattle, live cattle, lean hogs), nine metals (gold, platinum, silver, palladium, copper, aluminium, lead, nickel, zinc) and six softs (cocoa, sugar, orange juice, coffee, cotton, lumber). All commodity futures are priced in US dollars.

The US interest rate market has three major sources of aggregate risk, which are represented by three named risk factors: level, steepness and curvature (Litterman and Scheinkman, 1991). The interest-rate level risk factor is the dominant risk factor. The interest-rate data sample consists of the three future contracts that are closest to maturity for four interest rates: 2-year, 5-year, 10-year and 30-year.

The equity-market data sample consists of the three future contracts that are closest to maturity for four US equity indices: S&P500, DJIA, Russell 1000 and NASDAQ. These four equity indices provide sufficient information to estimate a proxy for a US equity market risk factor.

The US dollar is usually classified as wholly systematic when constructing a set of (statistical) risk factors from a group of US dollar bilateral exchange rates (Lustig et al., 2011). The FX-market data sample consists of the three future contracts that are closest to maturity for the US dollar, which provide sufficient information to estimate a proxy for the US dollar risk factor in the FX market.

3. Results

3.1 Model structure

We use a four-level integrated multifactor model to capture the multiple levels of heterogeneity within the commodity market and the commodity market’s relationship with other asset classes. We estimate the risk factors for each multifactor model in each level by principal components analysis.

Table 1 displays the overall structure of our proposed four-level integrated multifactor model. Although the overall structure exists on four levels, the structure for each asset class can exist on a different number of levels. For example, the structure of both the US interest rate market and the US equity market exist on three levels.

Table 1: Structure of the four-level multilevel integrated model

Commodity Market	Interest Rate Market	US Equity Market	FX Market
Commodity			
Sector	Interest rate	US equity index	
Commodity market	Interest rate market	US equity market	FX Market
Cross-market	Cross-market	Cross-market	Cross-market

When modelling term structures of futures prices by principal components analysis, the first risk factor usually represents a parallel shift for all futures prices and explains a significant proportion of fluctuations in the term structure (see Alexander, 2001).

Furthermore, in this paper, we use a single systematic risk factor for each risk model in level one. Including a second 'slope', or 'steepness', risk factor to measure common risk for either normal backwardation (downward sloping futures curve) or contango (upward sloping futures curve) remains a question for future research.

Figure 1 displays a graphical representation of the overall structure of the proposed four-level integrated multifactor model. To keep the figure readable, the level one risk models are excluded.

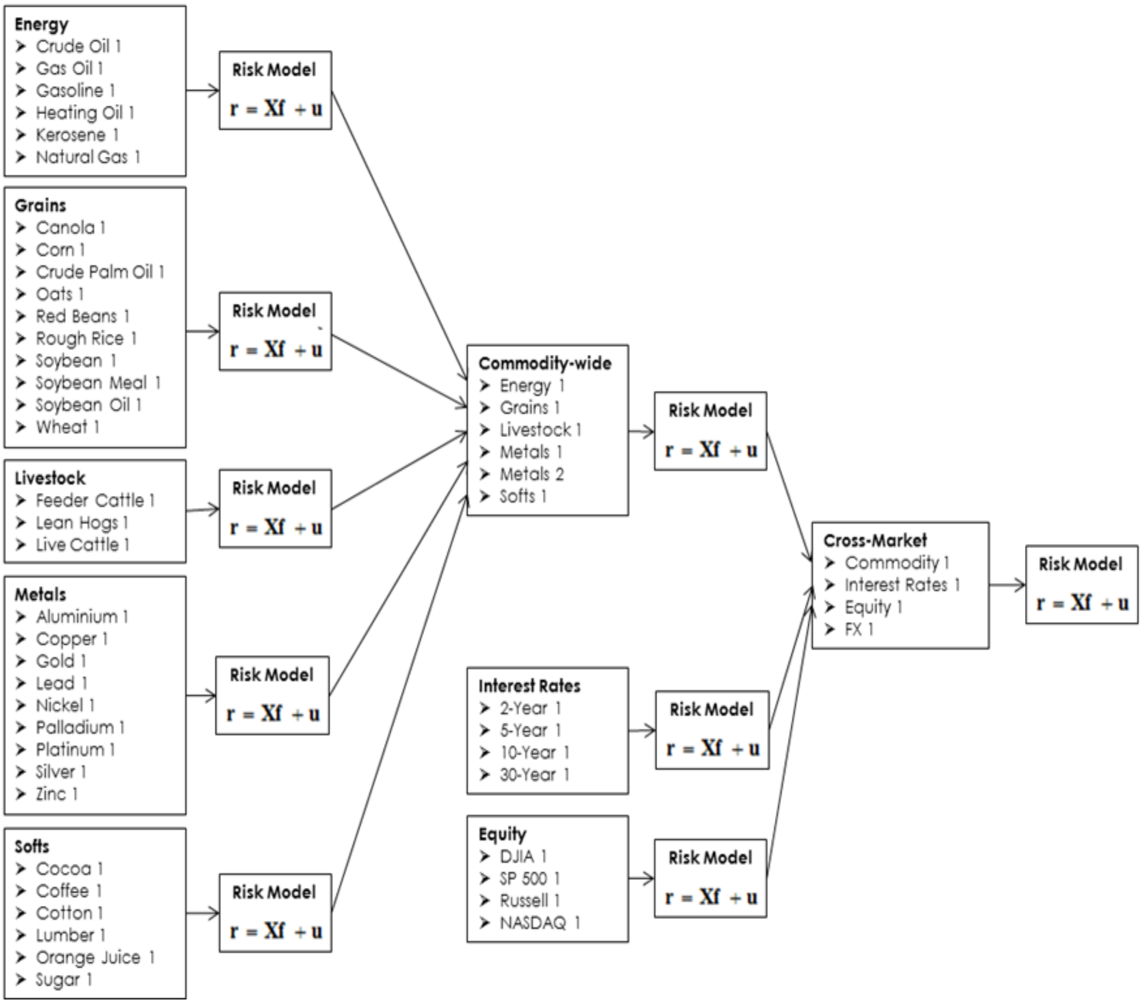

Figure 1: Structure of the four-level integrated multifactor model

In level one (n=1), the security returns are the returns of the three future contracts that are closest to maturity for each asset: commodity, interest rate, equity index, or exchange rate. A single future-level risk factor is produced for each level-one multifactor model.

For example, Table 2 displays the factor loadings for the crude oil risk factor resulting from a principal components analysis. The factor loadings are all positive and of a similar magnitude across the three future contracts. The single crude oil risk factor explains 98.2% of the total variation in the three crude oil futures returns, and represents a parallel shift for all crude oil futures prices.

Table 2: Factor loadings for the crude oil risk factor

Crude Oil Futures	Factor 1
Future 1	0.570
Future 2	0.585
Future 3	0.577

The FX multifactor model for level one uses the returns for the three US dollar future contracts to create a single FX-market risk factor. The structure of the FX market exists on only two levels. Therefore, the single FX-market risk factor directly enters the cross-market multifactor model (see Figure 1).

In level two (n=2), the level-one multifactor models are aggregated. For example, the commodity multifactor models from level one are aggregated within the five sector multifactor models in level two. Each sector-level multifactor model resulted in a single sector-level risk factor, except the metals multifactor model, which resulted in two sector-level risk factors.

Table 3 displays the factor loadings for the two risk factors associated with the metals sector. The first factor loadings (Factor 1) are all positive for all commodity-level risk factors. Thus the first risk factor represents a parallel shift for all commodities in the metals sector. The second factor loadings (Factor 2) are positive for the precious metals of gold at 0.605, silver at 0.528 and platinum at 0.281, and negative for the rest. Thus the second risk factor represents a precious metals versus base metals risk factor.

Table 3: Factor loadings for the two metals risk factors

Commodity Factors	Factor 1	Factor 2
Aluminium 1	0.356	-0.204
Copper 1	0.358	-0.206
Gold 1	0.256	0.605
Lead 1	0.337	-0.295
Nickel 1	0.340	-0.140
Palladium 1	0.339	-0.036
Platinum 1	0.352	0.281
Silver 1	0.293	0.528
Zinc 1	0.354	-0.291

The four interest rate multifactor models from level one are aggregated into a single interest-rate-market multifactor model, where a single market-wide risk factor is produced as a proxy for the level risk factor.

The four equity index multifactor models from level one are aggregated into a single US equity-market multifactor model, where a single market-wide risk factor is produced as a proxy for the equity-market risk factor for the US equity market.

In level three (n=3), the five sector multifactor models from level two are aggregated into a single commodity-market multifactor model, where a single market-wide risk factor is produced for the commodity market.

Table 4 displays the sector loadings associated with the single commodity-market risk factor. The risk factor loadings are large and positive for four out of the six sector risk factors: 0.493 for the energy sector (Energy 1); 0.465 for the grains sector (Grains 1), 0.521 for the first risk factor of the metals sector (Metals 1) and 0.517 for the softs sector (Softs 1). Thus the single commodity-market risk factor can be seen as a proxy for the commodity market. However, the livestock sector moves independently from all the other commodity sectors, with a very small factor loading of 0.043.

Finally, in level four (n=4), the four market-wide multifactor models (commodity market, US interest rate market, US equity market, and FX market) are aggregated into a single cross-market multifactor model. This model decomposes the market-wide risk factors into cross-market systematic and market-wide specific contributions.

Table 4: Factor loadings for the commodity-market risk factor

Sector Factors	Factor 1
Energy 1	0.493
Grains 1	0.465
Livestock 1	0.043
Metals 1	0.521
Metals 2	0.003
Softs 1	0.517

Table 5 displays the loadings associated with the single cross-market risk factor. The risk factor loadings are positive for both the commodity market risk factor at 0.566 and the equity market risk factor at 0.540, and are negative for both the interest rate market risk factor at -0.328 and the FX market risk factor at -0.529. The single cross-market risk factor explains 62.3% of the total variation in the underlying four market-wide risk factors. Therefore, there is a common cross-market risk factor across all asset classes.

Table 5: Factor loadings for the cross-market risk factor

Market Factors	Factor 1
Commodity 1	0.566
Interest Rates 1	-0.328
Equity 1	0.540
FX 1	-0.529

3.2 Commodity Market Analysis

The structure of the commodity market exists on four levels. The total covariance matrix for the security returns in level one $\mathbf{V}_i^1$ from (2) can be decomposed into each level by:

$$\mathbf{V}_i^1 = \mathbf{\Sigma}_i^4 + \mathbf{\Omega}_i^4 + \mathbf{\Omega}_i^3 + \mathbf{\Omega}_i^2 + \mathbf{\Delta}_i^1, \qquad i = 1,\ldots,M^1 \qquad (3)$$

where $\boldsymbol{\Sigma}_i^4$ is the level-four systematic cross-market covariance matrix; $\boldsymbol{\Omega}_i^4$, $\boldsymbol{\Omega}_i^3$, and $\boldsymbol{\Omega}_i^2$ are three factor specific covariance matrices for level four (commodity market), level three (sector) and level two (commodity), respectively; and $\boldsymbol{\Delta}_i^1$ is the security (futures) specific covariance matrix from (2).

The estimated multilevel integrated multifactor model is used to decompose the total variance for commodity futures returns using (3). Table 6 displays the percentage contribution to variance averaged within each of the five commodity sectors.

Table 6: Percentage contribution to variance for each commodity future returns averaged within each commodity sector, where each row sums to 100%

Sector	Count	Cross-Mkt Systematic	Com-Mkt Specific	Sector Specific	Commodity Specific	Future Specific
Energy	6	34.3%	8.7%	29.7%	25.4%	1.9%
Grains	10	22.8%	5.8%	25.6%	42.6%	3.3%
Livestock	3	0.2%	0.1%	63.5%	29.0%	7.2%
Metals	9	32.6%	8.3%	36.7%	22.2%	0.3%
Softs	6	17.2%	4.4%	11.5%	64.4%	2.5%
Average	**34**	**24.4%**	**6.2%**	**30.1%**	**36.8%**	**2.4%**

The cross-market (Cross-Mkt) systematic column represents the average percentage of the total variation in commodity futures returns that is explained by the single cross-market risk factor. The overall average of 24.4% demonstrates that about a quarter of the commodity market is integrated with other asset classes. The energy sector is the most integrated with 34.3%. In comparison, the livestock sector is the least integrated with 0.2%.

To measure the level of heterogeneity within the commodity market, we look at the amount explained by the commodity-market (Com-Mkt) systematic, which is found by adding the cross-market systematic plus the commodity-market specific columns. The commodity-market systematic represents the percentage of total variation in commodity futures returns that is explained by the single risk factor for the whole commodity market. The overall average of 30.6% (24.4% + 6.2%) demonstrates that approximately 70% of the commodity market is heterogeneous. The livestock sector is the most heterogeneous (least homogenous) with an average of 0.3% (0.2% + 0.1%). Conversely, the energy sector is the least heterogeneous (most homogenous) with an average of 43.0% (34.3% + 8.7%).

The livestock sector is segmented from other asset classes and moves independently from all the other commodity sectors. The livestock sector also has the highest explanation from the sector-specific risk factor at 63.5%.

It is noteworthy that the average of the future-specific percentage contributions to variance is very small at 2.4%. Thus the first risk factors in the level-one multifactor models explain a significant proportion of fluctuations in the futures term structures. The average future-specific percentage contribution to variance is largest for the livestock sector with 7.2%, which indicates the presence of seasonality. The average future-specific percentage contribution to variance is smallest for the metal sector with 0.3%, where seasonality is rarely present.

An alternative measure of the level of heterogeneity in the commodity market is to look at the amount explained by the sector systematic (sector risk factors), which is found by adding the cross-market systematic plus the commodity-market specific plus the sector specific columns. The sector systematic represents the percentage of total variation in commodity futures returns that is explained by the six sector-level risk factors. The overall average of 60.7% (24.4% + 6.2% + 30.1%) demonstrates that there is common structure at different levels of the commodity market.

3.3 Cross-market Analysis

Table 7 displays the correlation matrix for the market-wide risk factors. These include one commodity-market risk factor (Commodity 1), one US interest rate market risk factor (Interest Rates 1), one US equity market risk factor (Equity 1) and one FX market risk factor (FX 1).

Table 7: The correlation matrix for the market-wide risk factors. We denote by *, **, and * as showing sufficient evidence to reject the null hypothesis of zero correlation at the 10% level, the 5% level, and 1% level, respectively**

	Commodity 1	Interest Rates 1	Equity 1	FX 1
Commodity 1	**1.000**			
Interest Rates 1	**-0.278****	1.000		
Equity 1	**0.667*****	-0.409***	1.000	
FX 1	**-0.742*****	0.210*	-0.558***	1.000

The risk factor for the commodity market (Commodity 1), which explains 30.6% of the total variation in commodity futures returns, is significantly correlated with the risk factors from the other asset classes: +66.7% with the risk factor for the US equity market (Equity 1); -74.2% with the risk factor for the FX market (FX 1); and -27.8% with the risk factor for the US interest rate market (Interest Rates 1). Thus, a part of the commodity market appears to be significantly integrated with other asset classes.

4. Conclusion

Multilevel integrated multifactor models are capable of measuring the different levels of heterogeneity within the commodity market and of measuring the level of cross-market integration that the commodity market has with other asset classes.

We found that the commodity market is approximately 70% heterogeneous, with one commodity-market risk factor explaining 30.6% of the total variation in commodity futures returns. However, at the sector level, the commodity market is approximately 40% heterogeneous, with six sector-level risk factors explaining 60.7% of the total variation in commodity futures returns. These results indicate that there is common structure within the commodity market that exists at different levels.

We also found that approximately 25% of the commodity market is integrated with other asset classes. More specifically, there is a significant part of the systematic variation of the commodity market that is integrated with other asset classes. Therefore, the commodity market may not offer the level of diversification that is currently expected by investors. If investors choose to add commodities to their portfolios, they should be aware that they may be unintentionally increasing their exposure to other asset classes.

Further research is required to test the robustness of our results. For example, further research is required to investigate whether the observed level of integration in our post-financial-crisis data sample is present in previous periods.

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